EERC Technology… Putting Research into Practice

The Plains CO_2 Reduction (PCOR) Partnership

Wisconsin Carbon Sequestration Briefing
July 11, 2008

John Harju
Energy & Environmental Research Center

DOE Regional Carbon Sequestration Partnerships (RCSPs)

- Nationwide network of regional partnerships
  - Determine the best approaches for capture and permanent storage of GHG.
  - Determine the most suitable technologies, regulations, and infrastructure needs for CO_2 capture, storage, and sequestration.
  - Geographic differences in sources and sinks dictate regional approach.
- Three phases
  - Characterization phase (2003–2005): characterized opportunities for carbon sequestration.
  - Validation phase (2005–2009): Small-scale field tests.
  - Deployment phase (2007–2017): Large-volume carbon storage tests.

Source: NETL Partnerships retrieved from www.netl.doe.gov/technologies/carbon_seq/partnerships/partnerships.html

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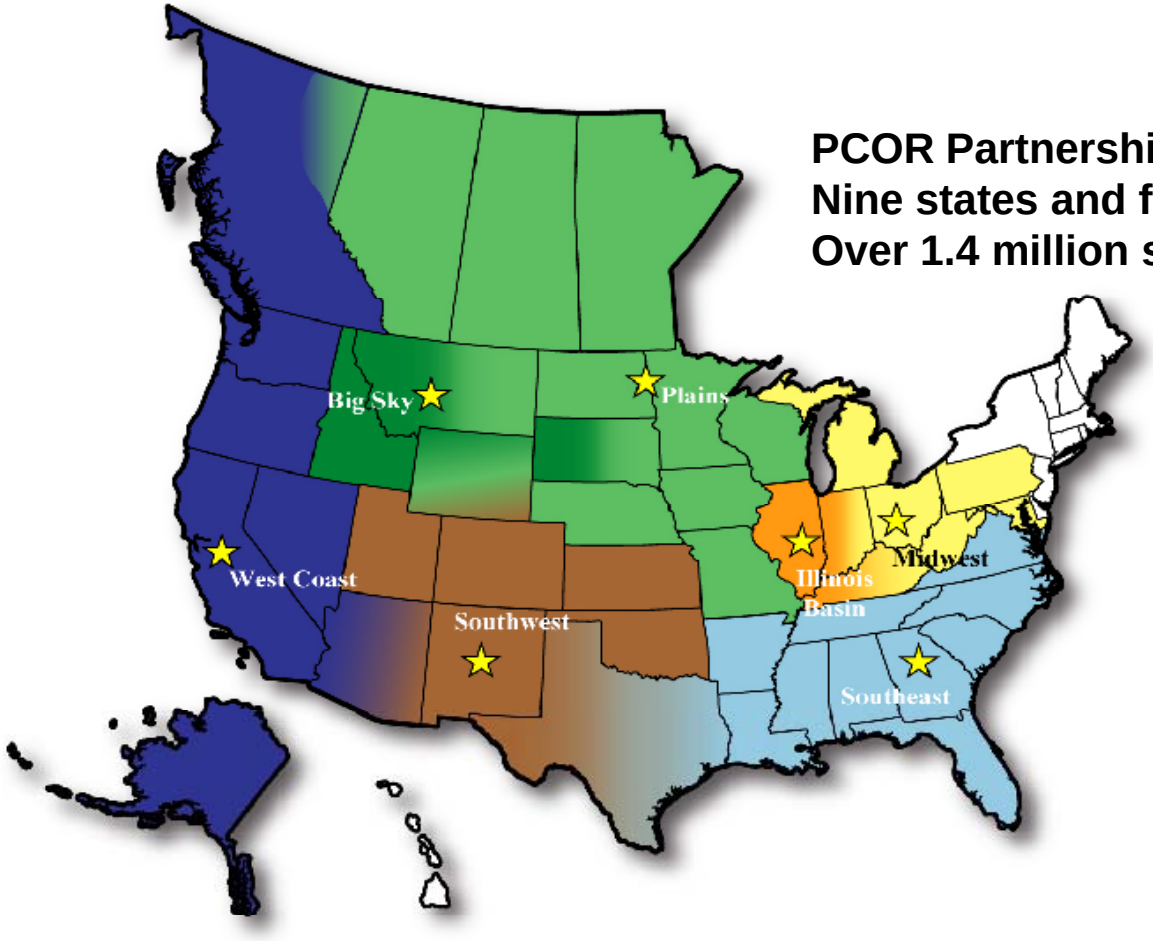
Regional Carbon Sequestration Partnerships



PCOR Partnership:
Nine states and four provinces
Over 1.4 million square miles

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Nine

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PCOR Partnership 2003–Present
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AIR PRODUCTS
Alberta
EUB
AERI
AGS
Ameren
ACCCE
AMERICAN LIGNITE ENERGY
Apache
BASIN ELECTRIC POWER COOPERATIVE
BECHTEL
Blue Source
BNI COAL
BRITISH COLUMBIA
Carbozyme Inc.
CCX
Chicago Climate Exchange
Dakota Gasification Company
Ducks Unlimited Canada
DUCKS UNLIMITED
Eagle Operating Inc.
EICCD
ENBRIDGE
Encore Acquisition Company
Environment Canada
EXCELSIOR ENERGY
Fischer Oil and Gas, Inc.
GREAT NORTHERN
GREAT RIVER ENERGY
HESS
HUNTSMAN
DNR
Kiewit
Manitoba Hydro
MARATHON
MEG Energy Corp
Melzer COnsulting
Minnesota Pollution Control Agency
minnesota power
Minnkota Power
MISSOURI DEPARTMENT OF NATURAL RESOURCES
MISSOURI RIVER
MONTANA-DAKOTA
Environmental Quality
MUREX PETROLEUM CORPORATION
National Commission on Energy Policy
Natural Resources Canada
Nexant
NORTH AMERICAN COAL CORPORATION
North Dakota DEPARTMENT OF COMMERCE
North Dakota Department of Health
NATURAL RESOURCES TRUST
NORTH DAKOTA PETROLEUM COUNCIL
NDSU
OTTER TAIL POWER COMPANY
ptrc Petroleum Technology Research Centre
PTRC
Prairie Public
Pratt & Whitney
RAMGEN
RPS Energy
Saskatchewan Industry and Resources
SaskPower
Schlumberger
Shell Canada Limited
Spectra Energy
STRATEGIC WEST ENERGY LTD.
SUNCOR ENERGY
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WESTMORELAND COAL COMPANY
Xcel Energy

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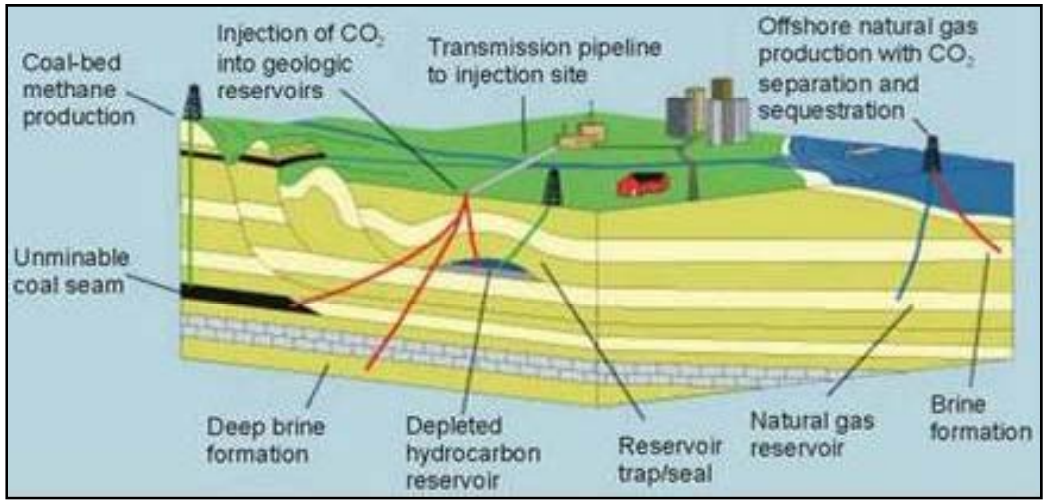
Phase II Project Objectives

- Develop solutions for capture, transport, and storage of CO_2 in the PCOR Partnership region.
  - Implementation of field validation tests that confirm the feasibility of regional and national sequestration technologies.
  - Continue regional characterization with respect to sequestration potential.
- Transfer results to DOE and other public and private stakeholders.
- Engage the public as stakeholders.



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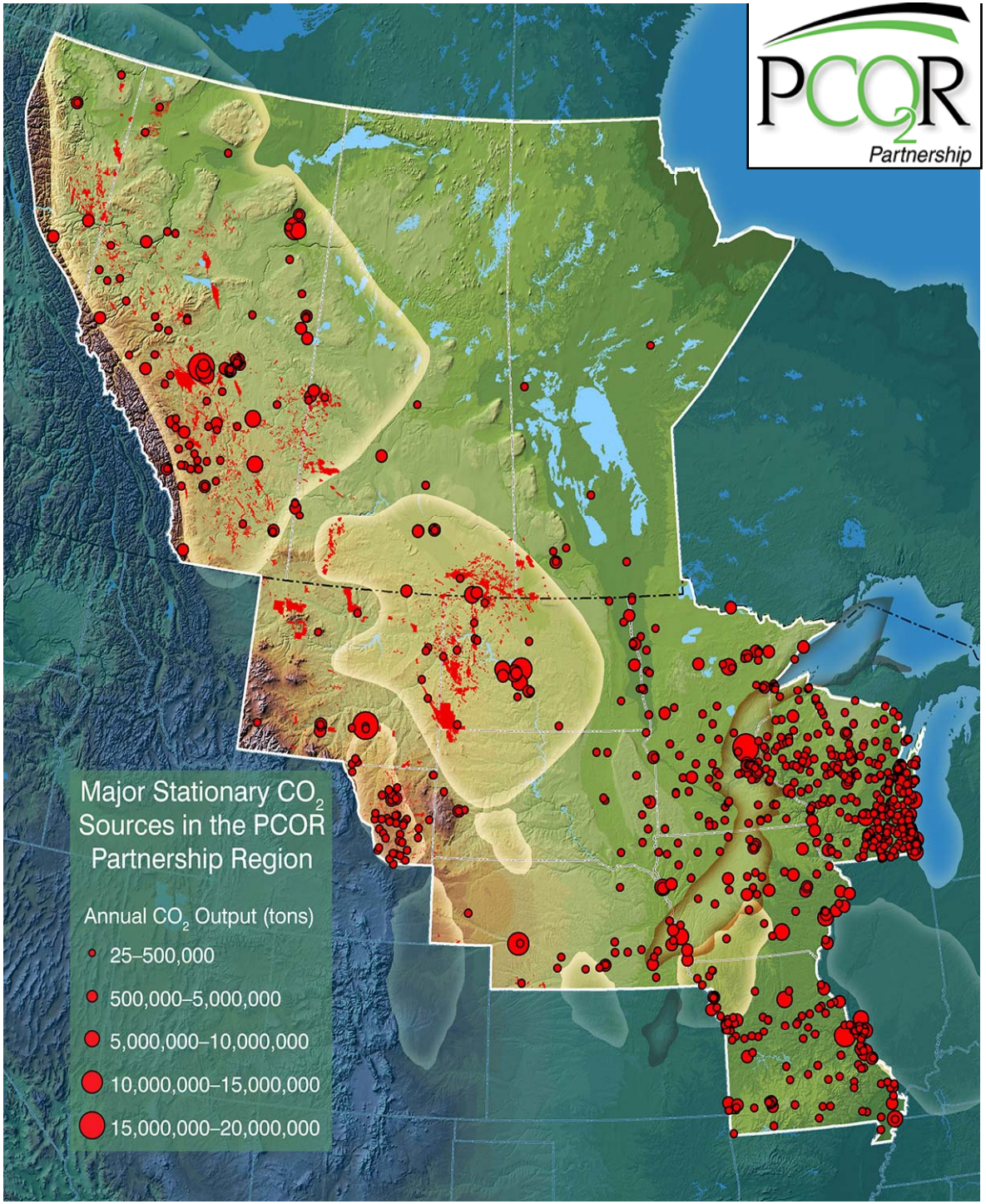
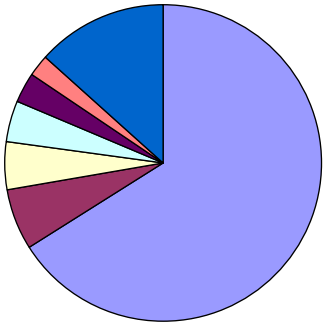


Sources

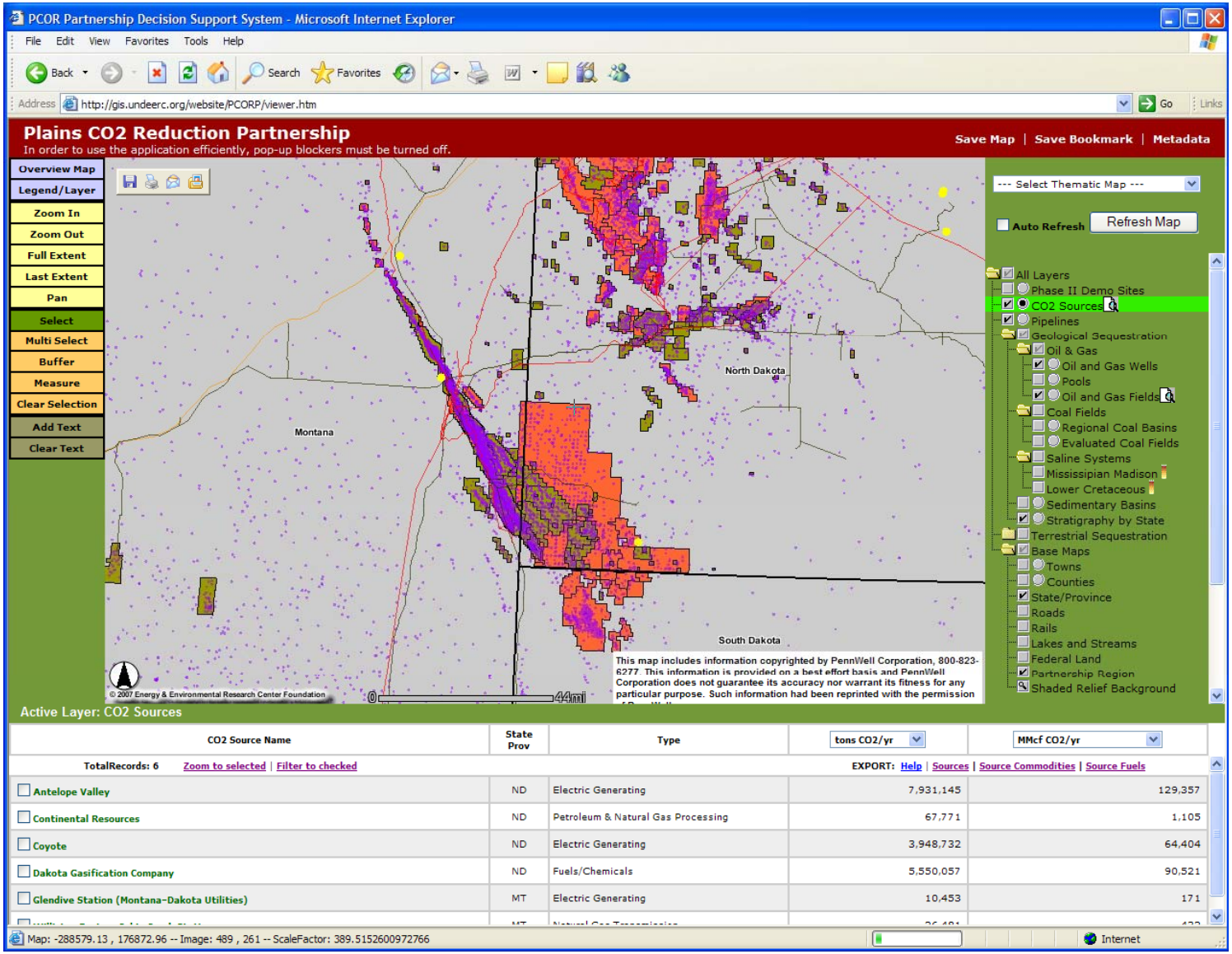
1106 stationary sources

Total CO_2 emissions:
≈ 549 million tons/yr

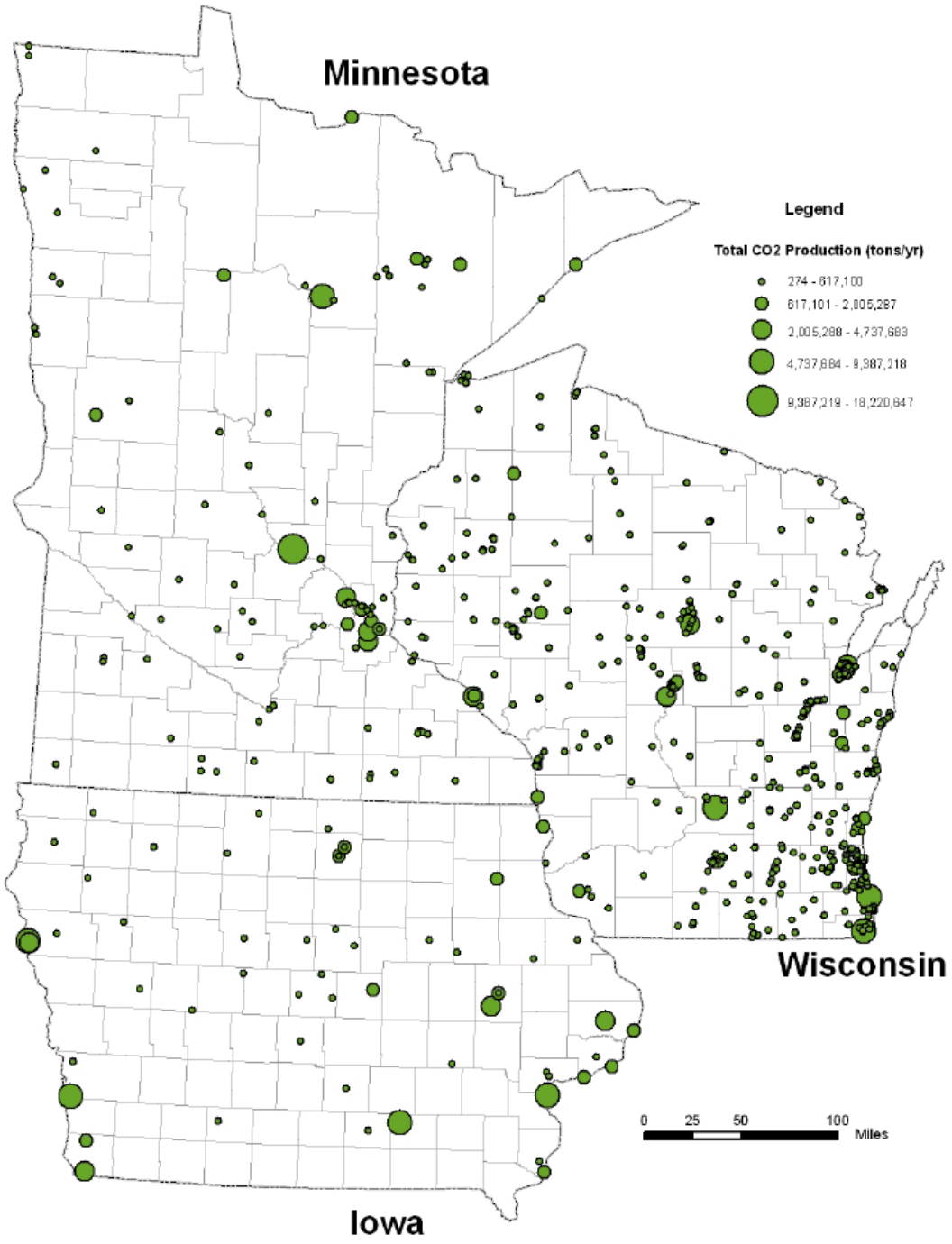


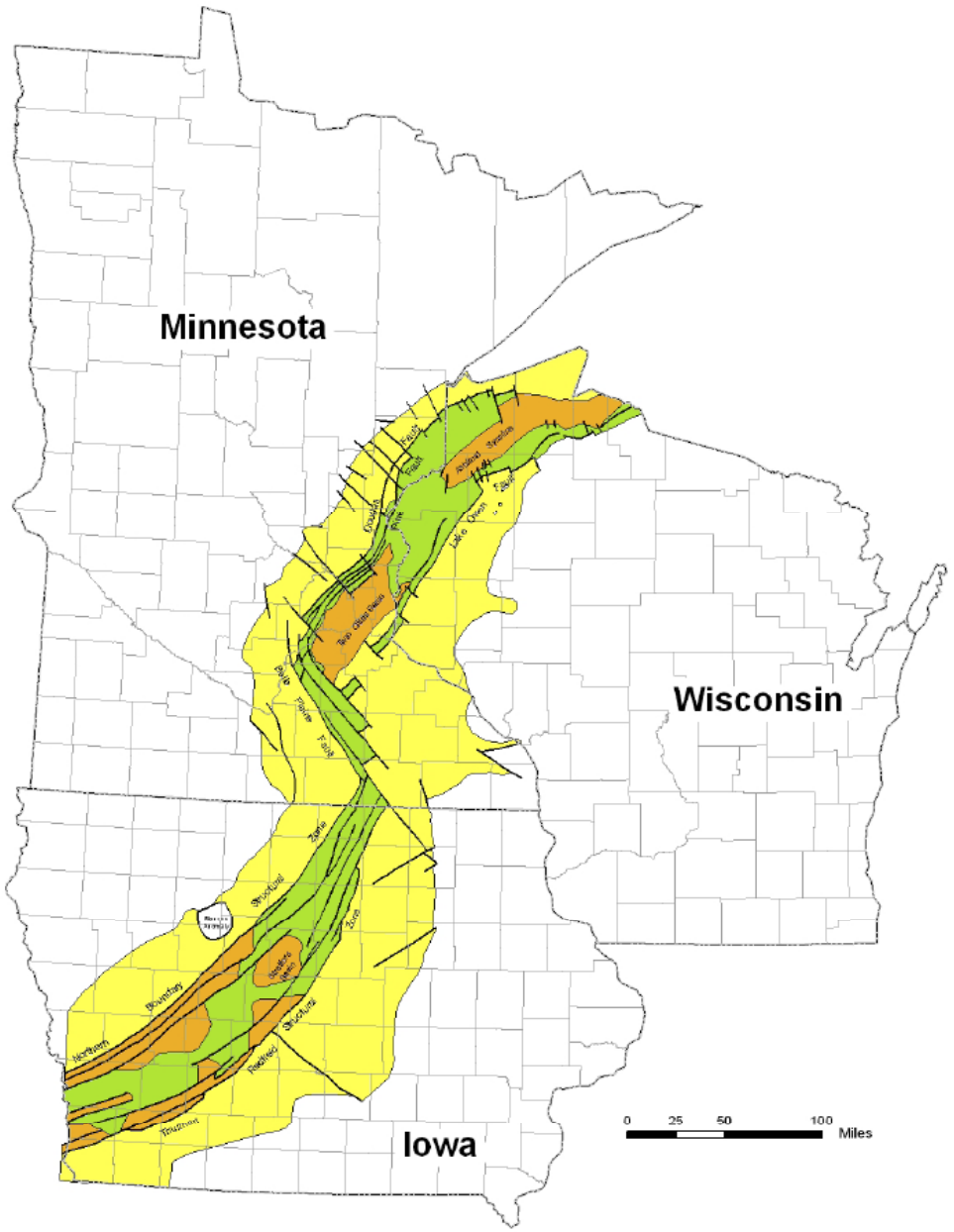
- Electricity Generation (66%)
- Paper and Wood Products (6.1%)
- Petroleum and Natural Gas Processing (5.2%)
- Ethanol Production (4%)
- Petroleum Refining (3.2%)
- Cement/Clinker Production (2.1%)
- All Others (agricultural processing, industrial/institutional heat and power, manufacturing, etc., 13.4%)

Decision Support System

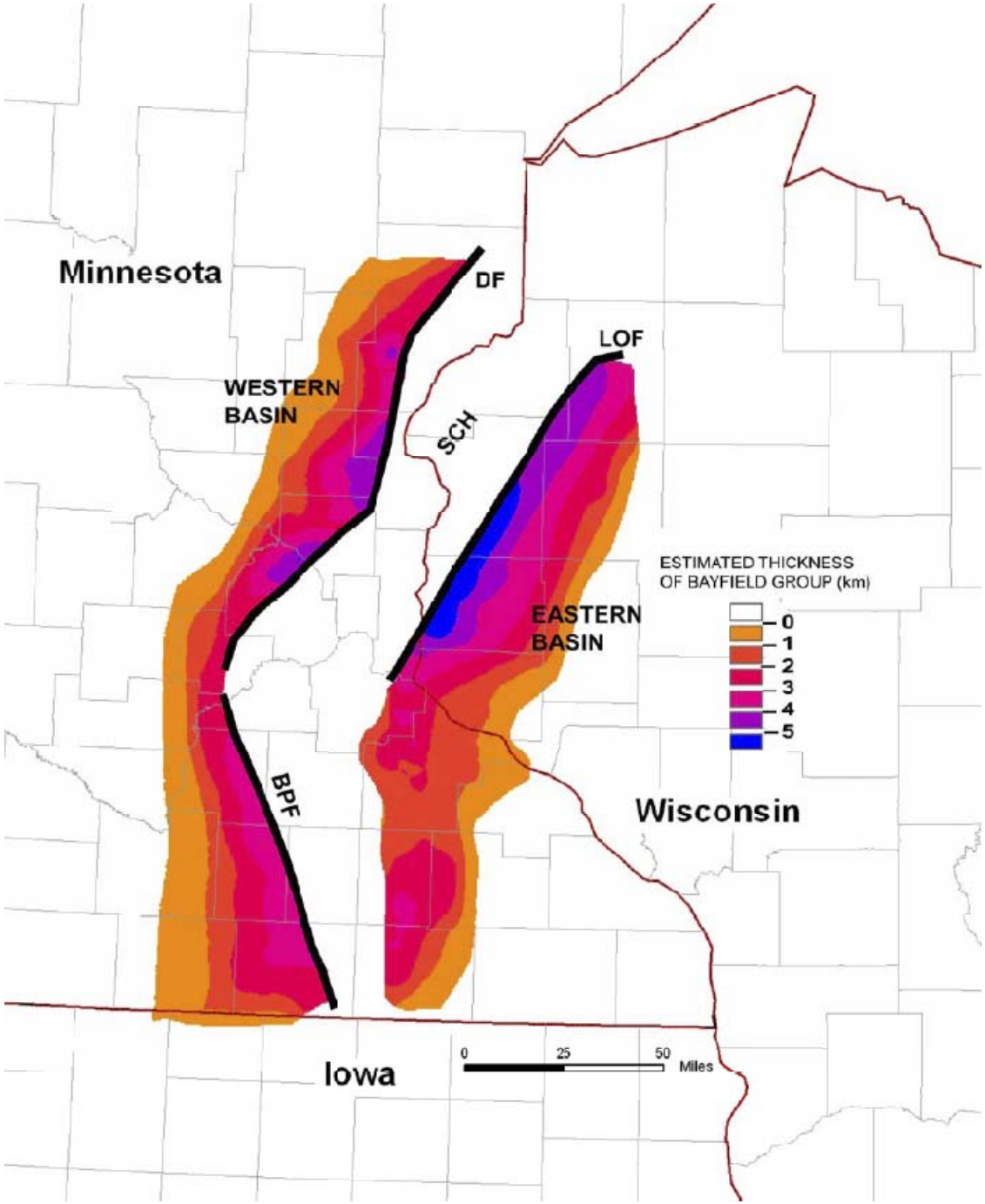


Stationary point sources of CO2 in Minnesota, Iowa, and Wisconsin, showing estimated annual emissions





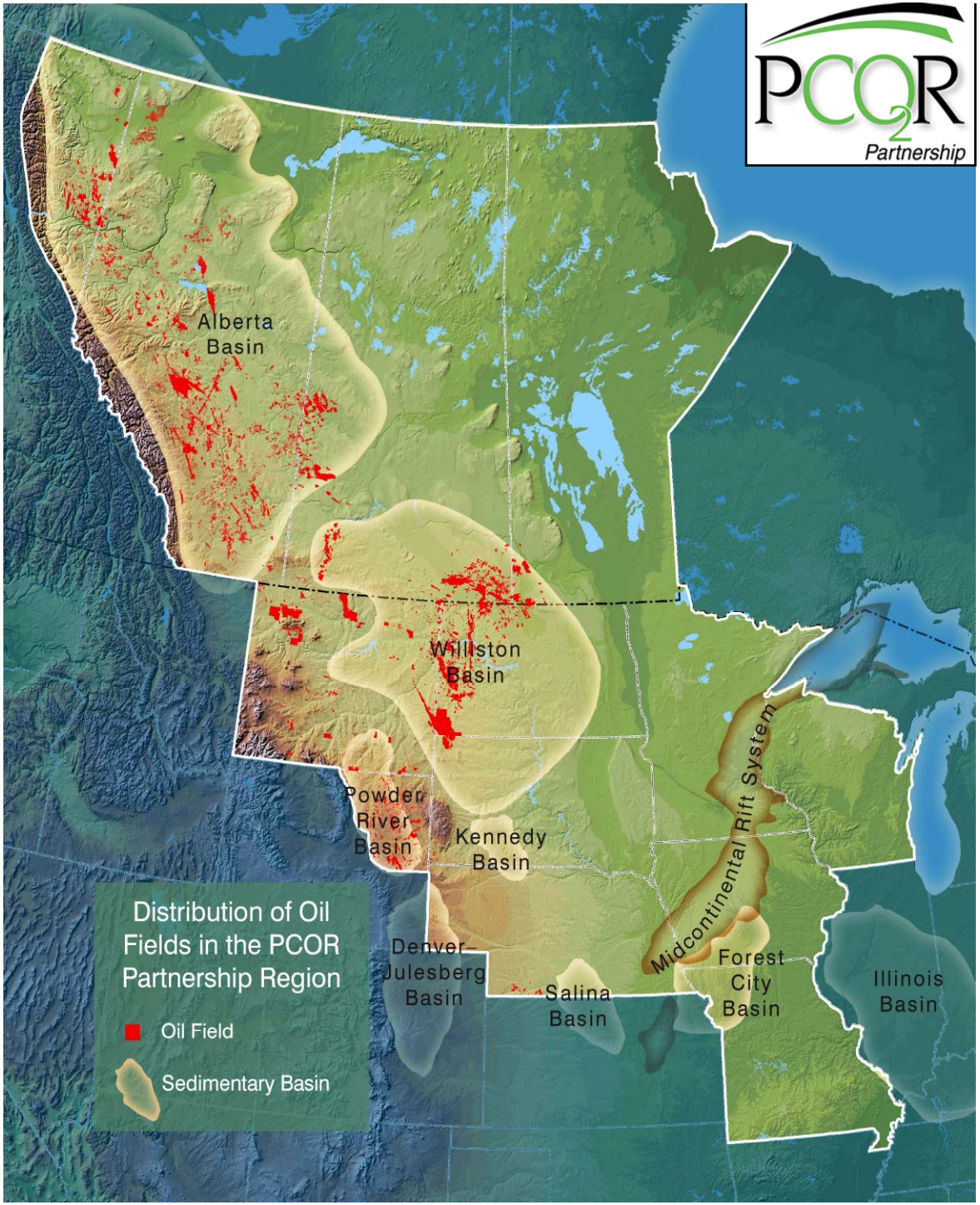
Extent of Midcontinent Rift rocks in Minnesota, Iowa, and Wisconsin, showing sandstone-dominated Bayfield Group and equivalent rocks in yellow, more gravel-rich Oronto Group and equivalent rocks in orange, and volcanic rocks in green (Minnesota Geological Survey Open File Report OFR-08-01)



Estimated thickness map for Bayfield Group rocks in Minnesota and Wisconsin, based on three-dimensional gravity modeling by Allen (1994). Abbreviations: DF, Douglas Fault; LOF, Lake Owen Fault, SCH, St. Croix Horst, BPF, Belle Plaine Fault. (Minnesota Geological Survey Open File Report OFR-08-01)

Challenges to MRS Characterization

- Lack of data.
- Iowa, Wisconsin, Minnesota are not oil and gas (O&G) producers and have been relatively lightly explored.
- Only a small number of O&G or water tests done in areas of interest.
- MRS – potentially an extensive target but data are lacking and expensive to obtain.



Oil Fields

3000 fields; 11,000 pools

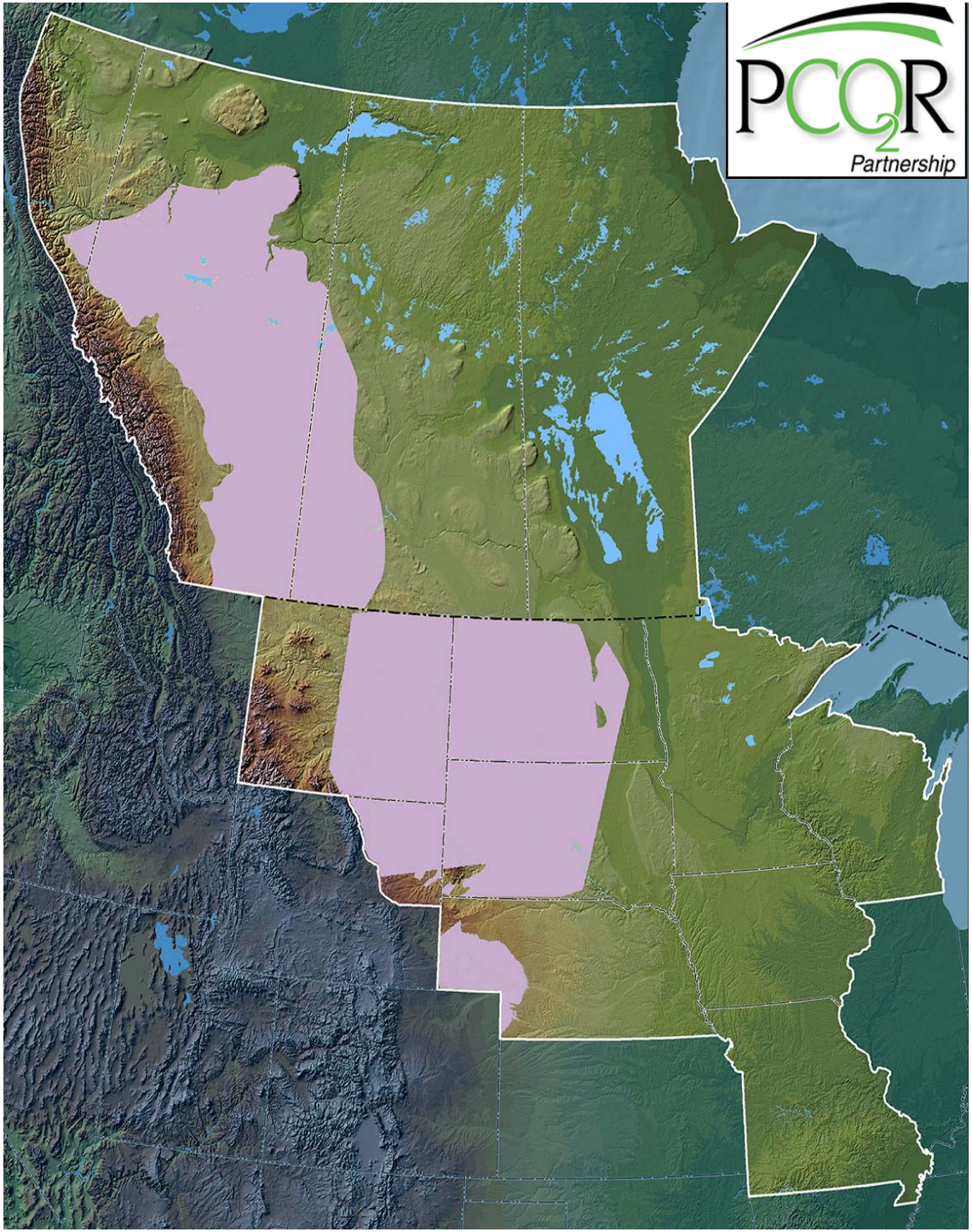
580,000 wells

Estimated Sequestration Capacity (based on 45% of fields having enough pool data to estimate capacity)

EOR approach: 6.9 GT

Incremental oil: >3 billion bbls

Volumetric approach: 30 GT



Saline Aquifers

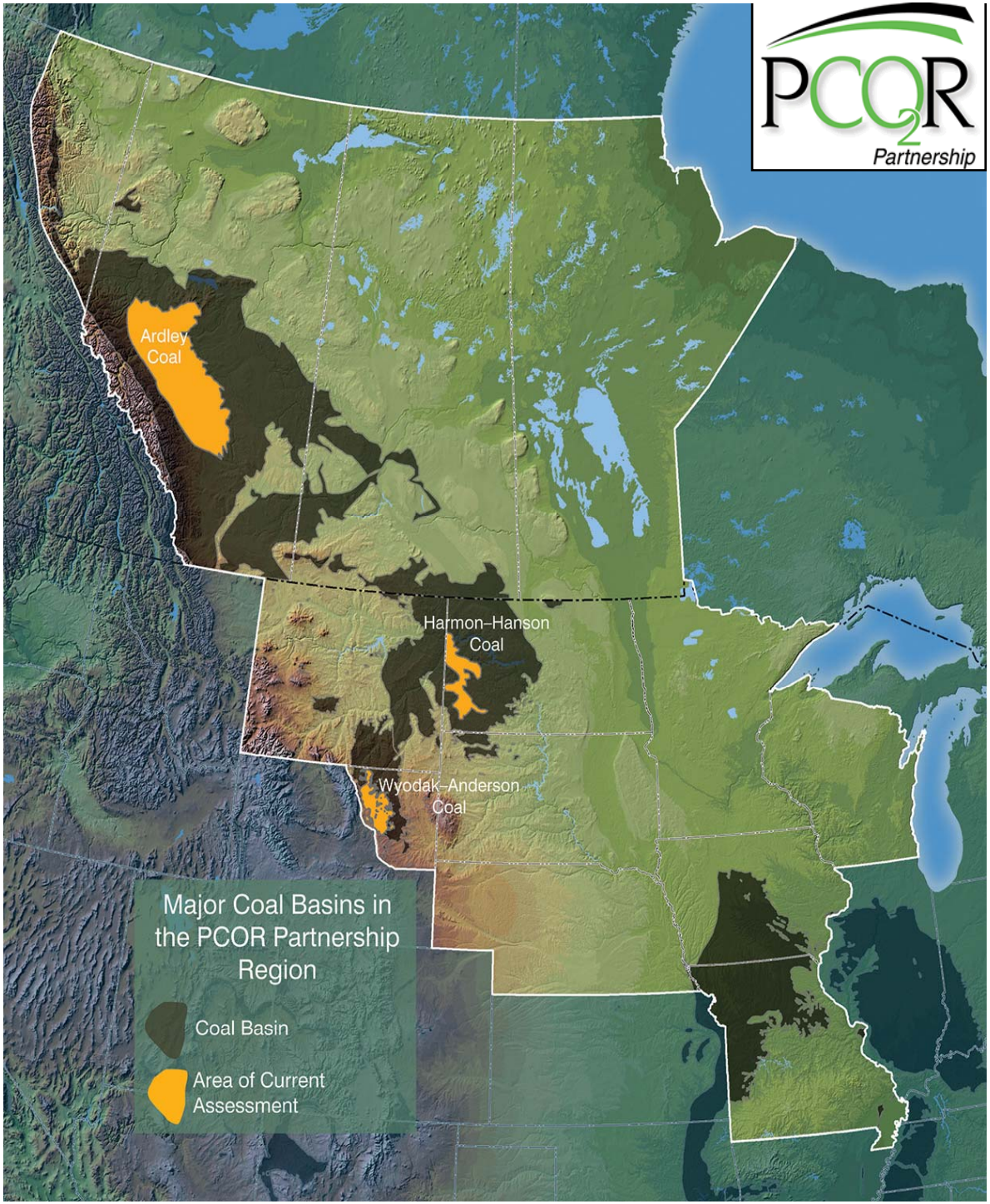
Two saline systems characterized:

- Mississippian Madison
- Lower Cretaceous

Two+ systems in progress

Three planned

Estimated sequestration capacity of characterized systems: 101–221 GT



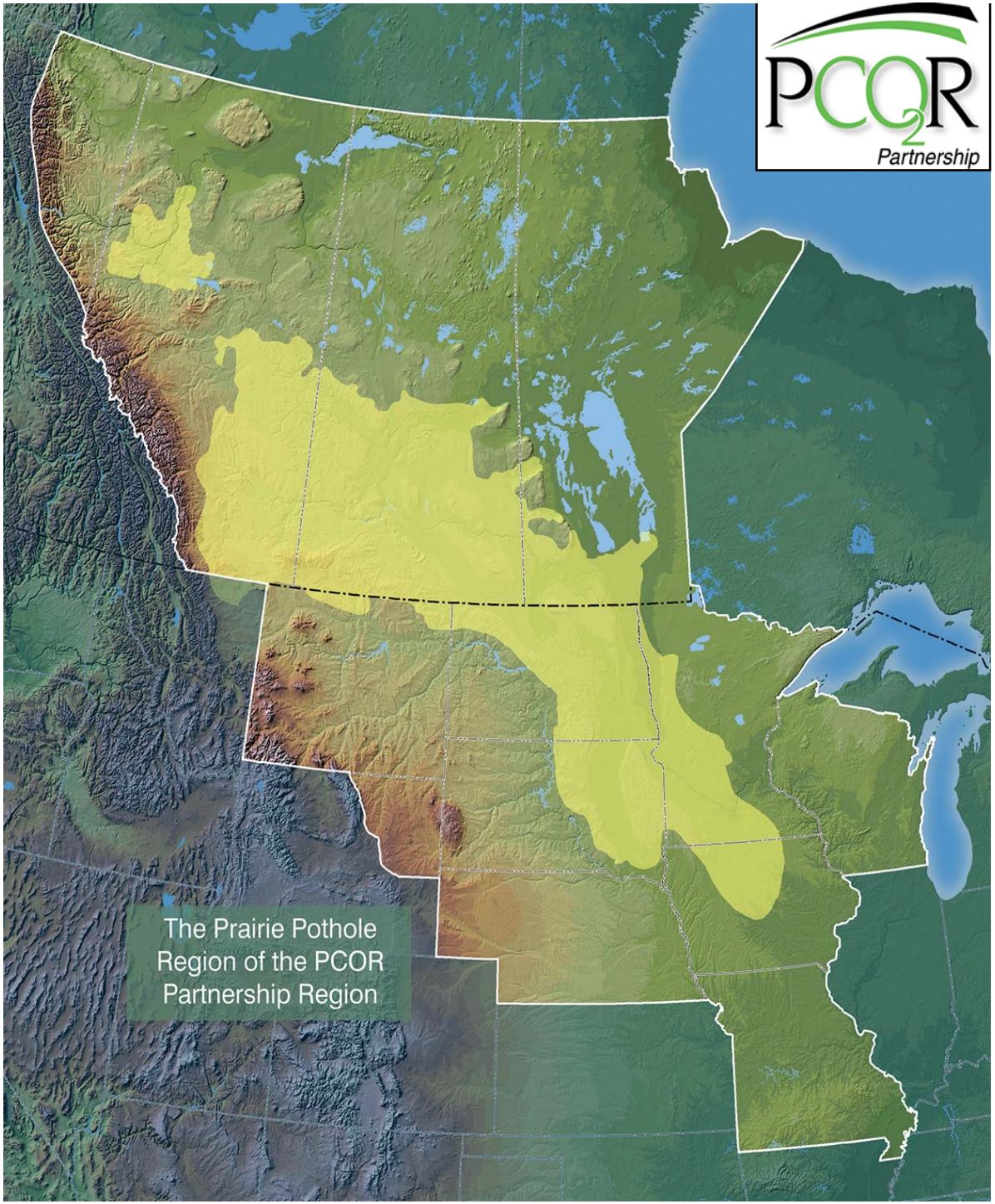
Coal

Three coalfields characterized:

- Ardley
- Harmon–Hanson
- Wyodak

Planned for Iowa and Missouri Geologic Surveys to work on respective coals.

Estimated sequestration capacity of characterized coalfields: 10.6 GT



Terrestrial

PPR and grasslands/croplands are being assessed.

Potential sequestration capacity over a 10-year period:

Wetlands: 220–450 million tons.

Vegetative standing crop in restored wetlands:
27 million tons

Grasslands/croplands:
under assessment (preliminary data in decision support system (DSS, ©2007 EERC Foundation)

Key Results of Phases I and II

- Tertiary-phase enhanced oil recovery (EOR) is the primary near-term opportunity for managing CO_2 in the PCOR Partnership region.
- Demand for CO_2 exceeds near-term supply.
- When CO_2 supply surpasses EOR demand, saline aquifers are available throughout the region to meet sequestration demand.
- Significant accumulations of unminable coal also represent potential opportunities for sequestration.
- Terrestrial opportunities represent a key near-term strategy to offset emissions, and the Prairie Pothole Region (PPR) represents a unique opportunity therein.

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Implications of Phase I and II Results

- EOR is key to regional economic development.
- The primary oil-bearing systems ***are saline formations***. The expertise, experience, and infrastructure developed through EOR will be directly applicable to non-EOR saline formation sequestration in the future.
- Additional saline formations are stratigraphically and geographically proximal to EOR opportunities.

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Regional Characterization Approach

Broad Approach

- Views region from a multistate, multiprovince perspective.
- Relied heavily on our partners to determine what data are relevant in characterizing the region.
- Data from partners, public databases and Web sites, agencies governing oil and gas exploration, and regulatory agencies.

Focused Approach

- Considers site-specific and local assessments that can serve as analogs for similar conditions in the PCOR Partnership region or outside of the region.
- Includes studies (demonstration sites as well as other focused studies) that are currently under way in Phase II and planned for Phase III.

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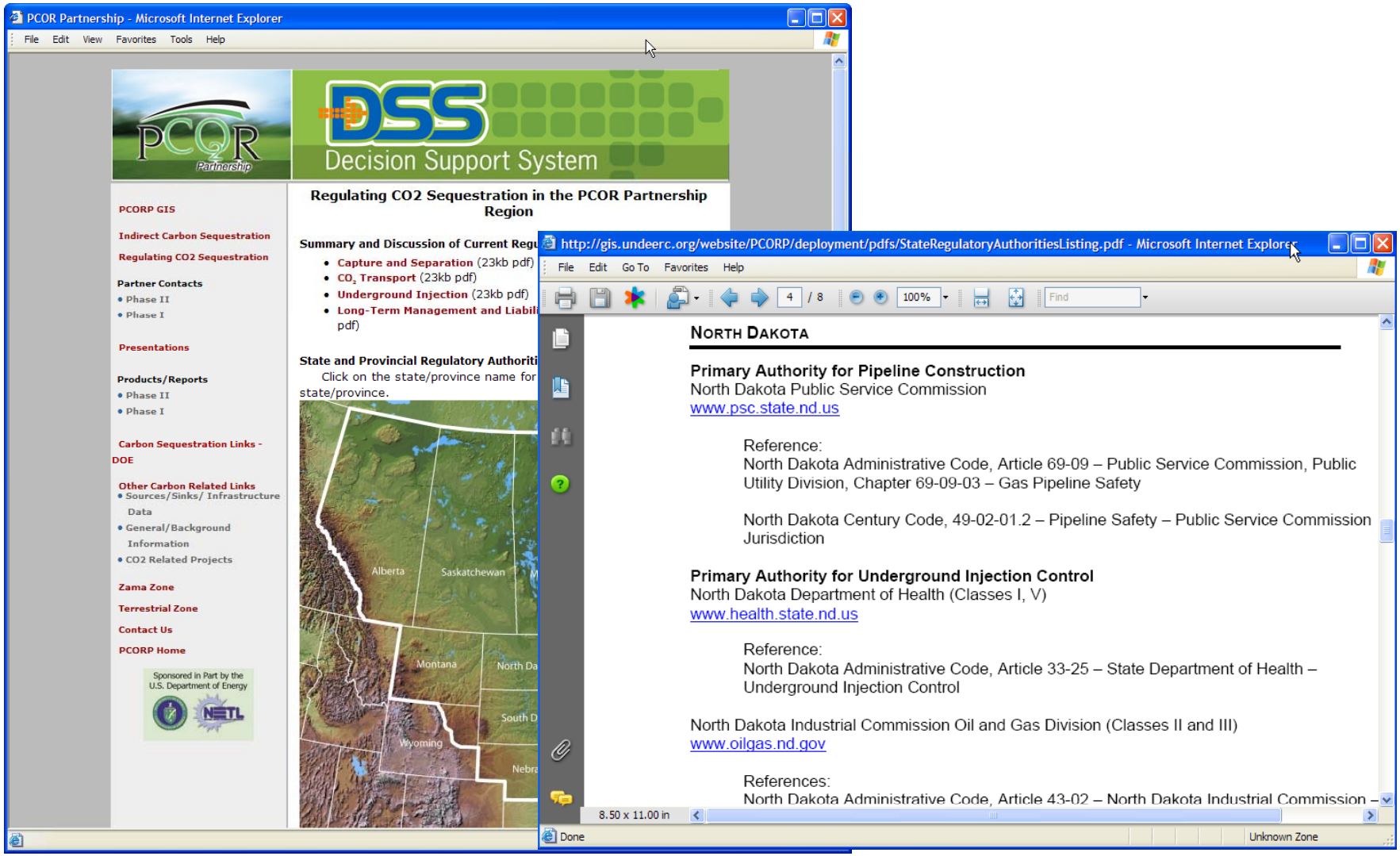
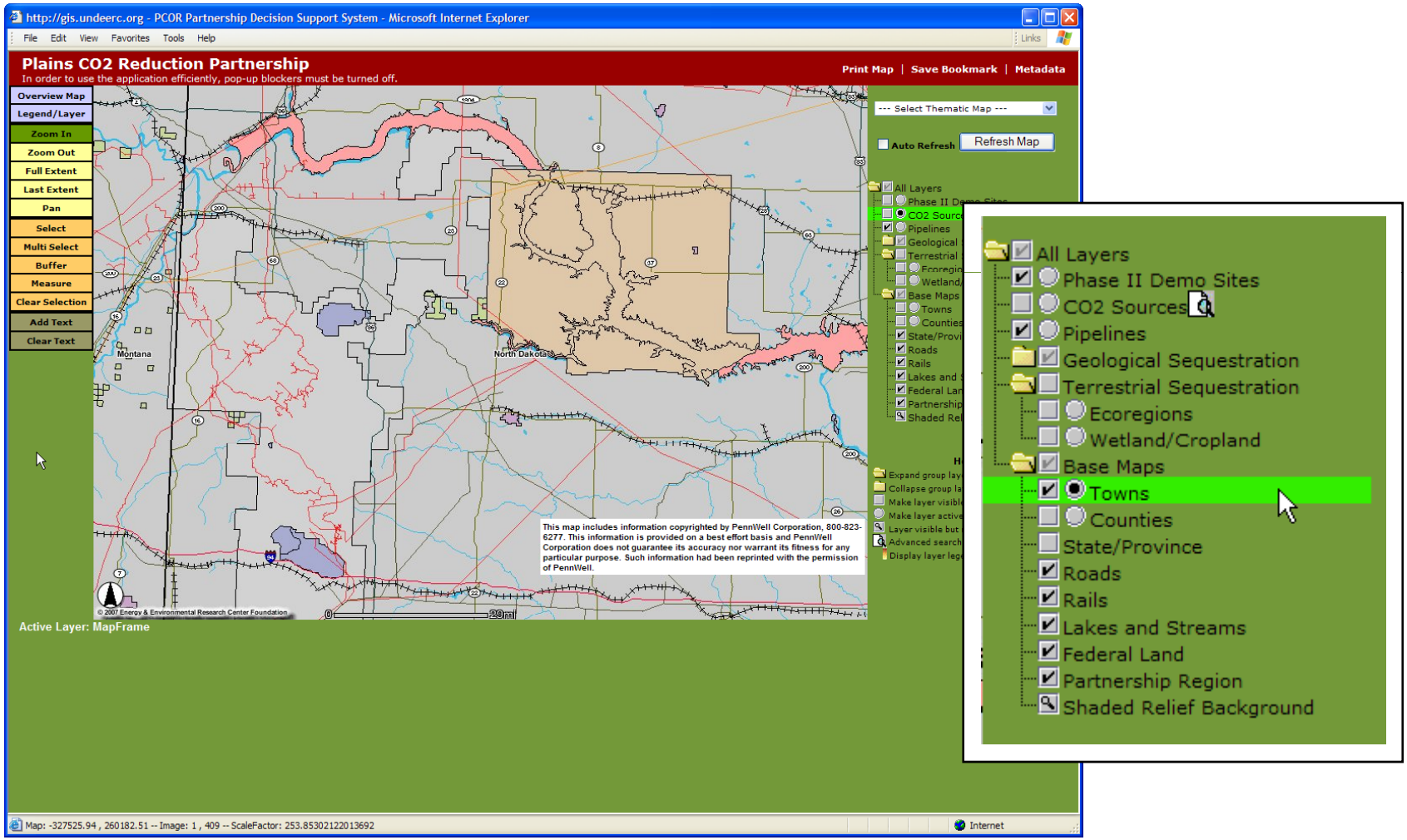
Regulatory Framework



Infrastructure



Regional Characterization Path Forward

- Data gap assessment
- Continued characterization
  - Refine existing data
  - Continue broad and focused data gathering and analysis
- DSS improvements
- Dissemination of results
  - DSS
  - DOE
  - NATCARB

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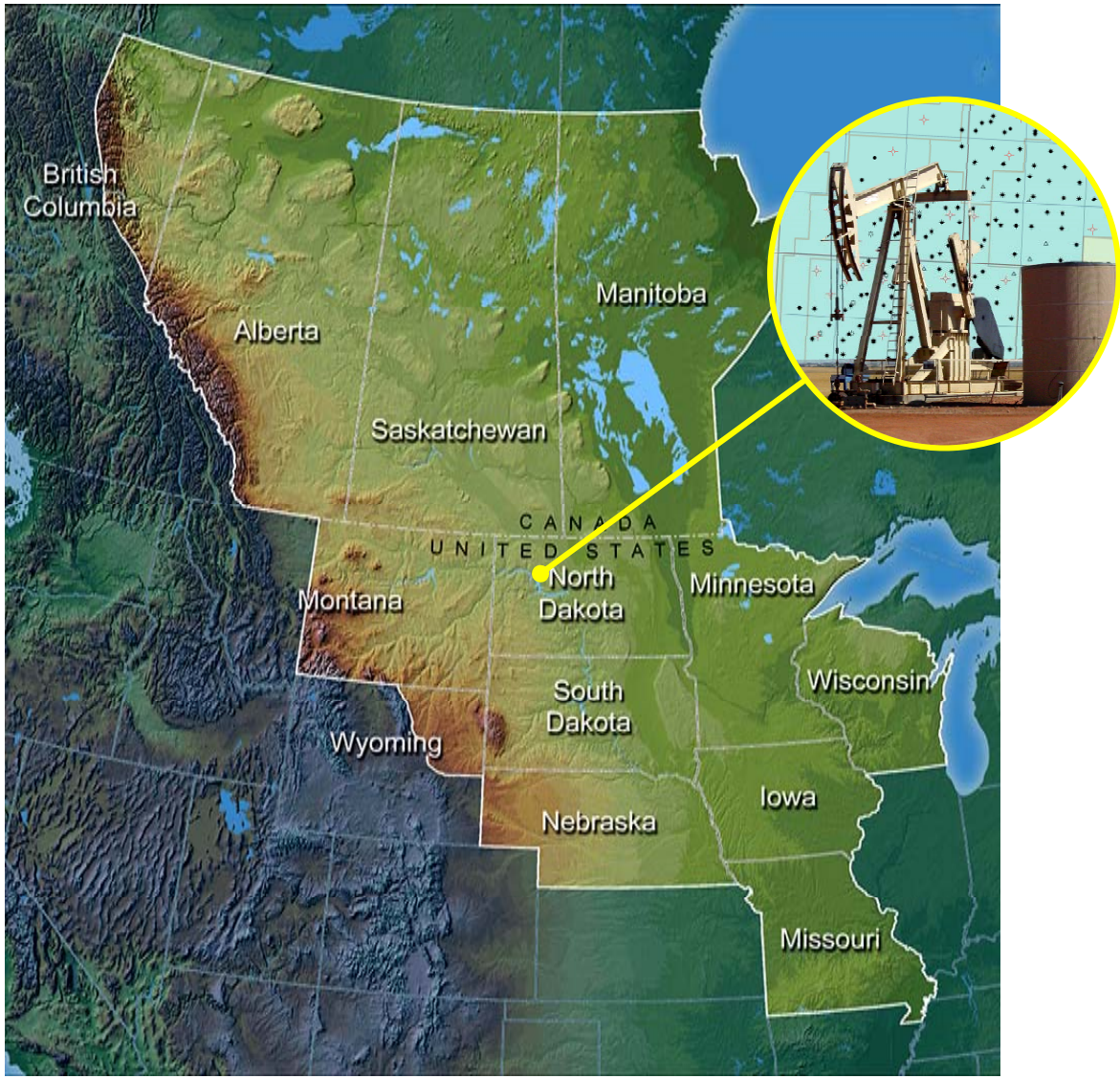
Field Validation Tests

Williston Basin CO_2 Sequestration and EOR Test



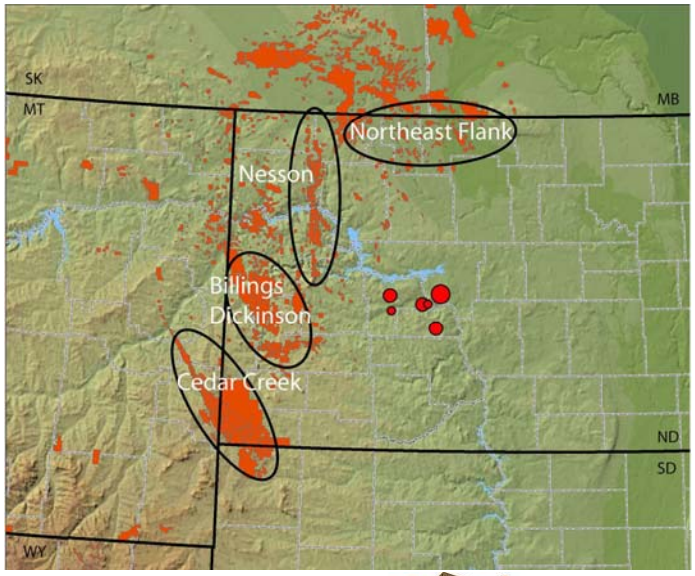
Williston Basin Test Goals and Objectives

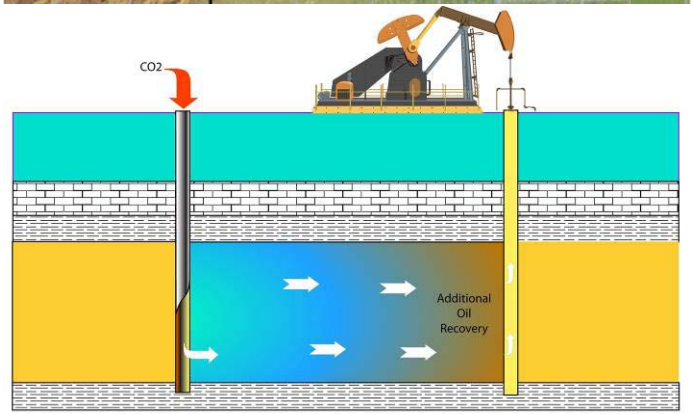
Goal

- To validate the sequestration of CO_2 in deep (>10,000 ft) carbonate oil reservoirs using cost-effective MMV approaches.

Objectives

- Inject pure CO_2 into a deep carbonate oil reservoir for simultaneous sequestration and EOR.
- Determine the effects of high pressure and temperature on sequestration, EOR, and MMV.
- Implement a cost-effective approach for MMV in a deep oil field.





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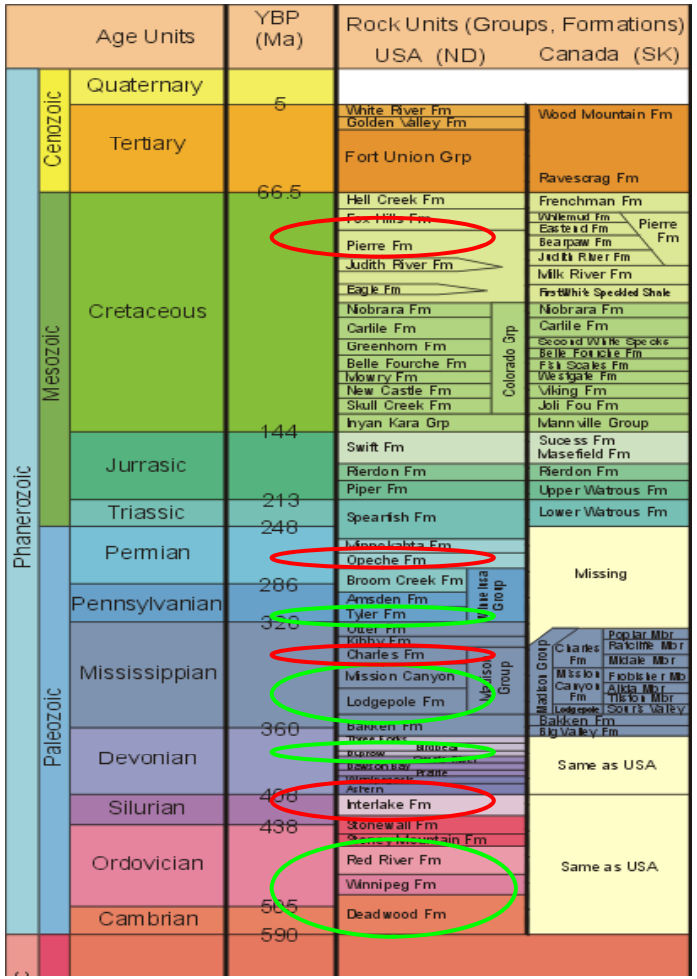
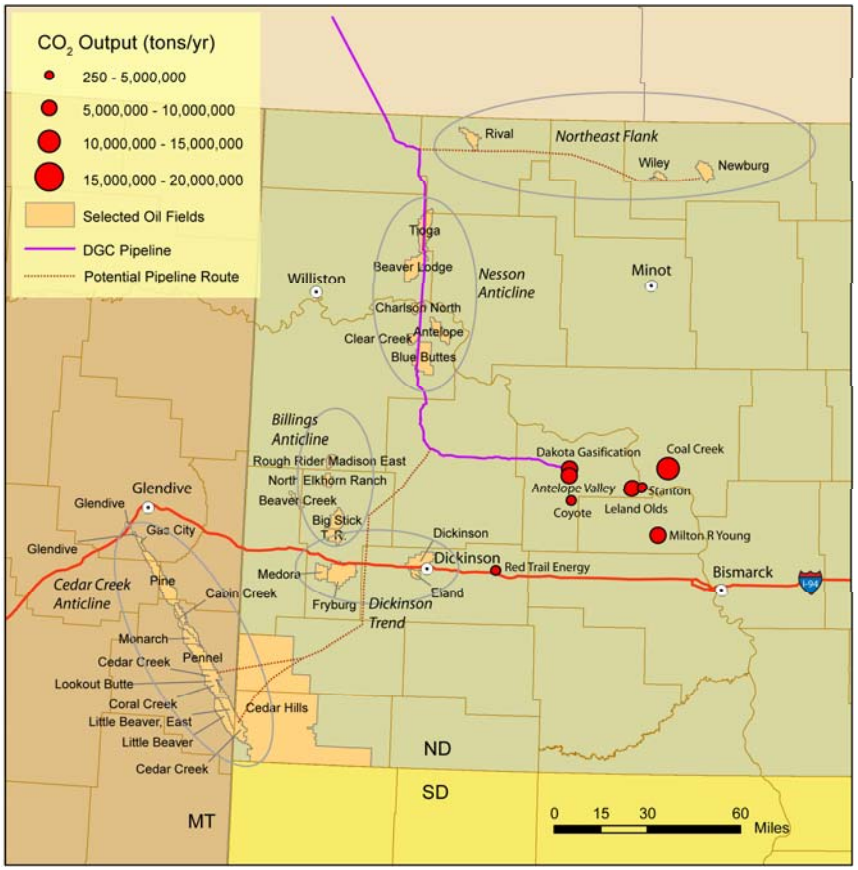
Key Williston Basin Results

- Many fields have multiple pools that may serve as sinks.
- Multiple zones of laterally continuous anhydrites, salts, and low-permeability shales provide multiple seals to many sites.
- Very little mineralogical change occurred under experimental conditions (some conversion of silicates – carbonates?).
- Industry interest in CO_2 flood EOR is offset by lack of readily available CO_2 in the area.
- Change in industry partner priorities and timing result in new plan.



Williston Basin Path Forward

- Pilot-scale CO_2 injection test on oil field in Williston Basin with commercial partner.
- Use existing data and tools to fast-track implementation of the new test.
- Geochemical modeling of target reservoir will be conducted.
- Geomechanical properties of reservoir and seal formation rocks will also be evaluated.
- MMV will likely focus on reservoir dynamics data, fluid analyses, tiltmeters, and/or microseismic monitoring.
- A Regional Technology Implementation Plan will be developed.



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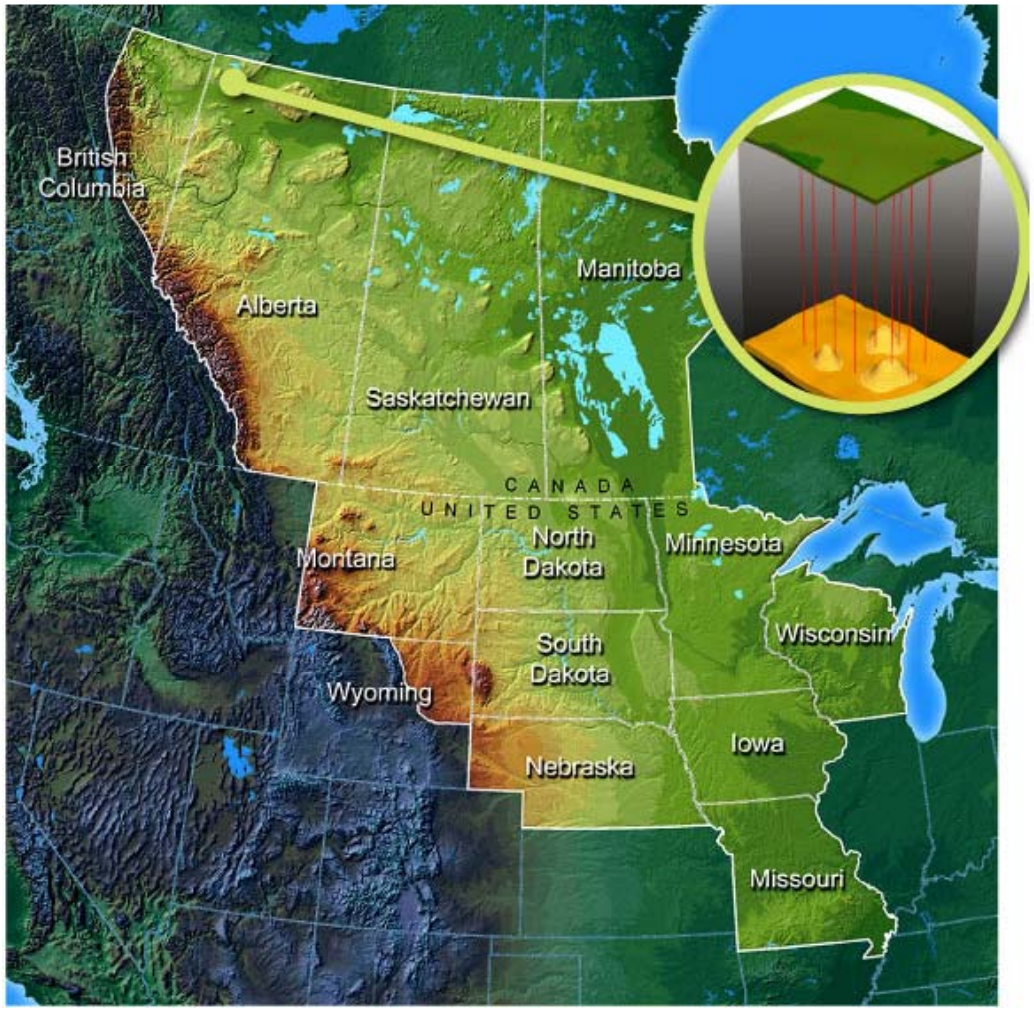
Zama Acid Gas EOR, CO_2 Sequestration, and Monitoring Project



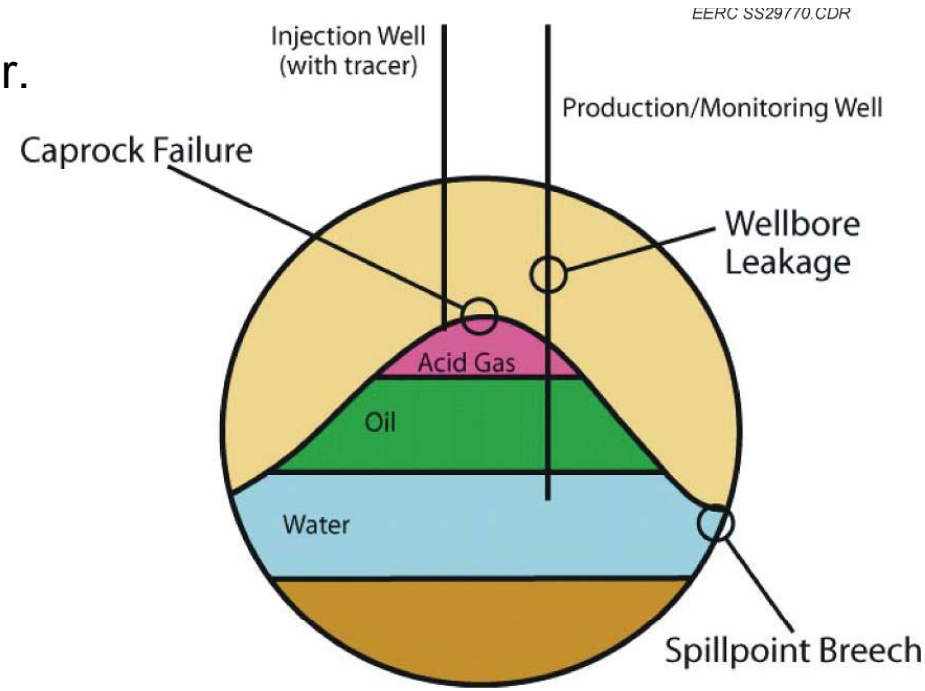
Zama Project Goals and Objectives

Goal

- To validate the sequestration of CO_2-rich acid gas in a depleted oil reservoir.

Objectives

- Inject a stream of acid gas (70% CO_2 – 30% H_2S) for simultaneous acid gas disposal, CO_2 sequestration, and EOR.
- Determine the effects of acid gas injection on target reservoir and cap rock formations.
- Implement a cost-effective approach for MMV for sequestration of a CO_2-rich acid gas stream.



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Project Recognition

Formally recognized by the Carbon Sequestration Leadership Forum in March 2007 as an official Geological Storage Project

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Zama Path Forward

- Injection of acid gas will continue through Year 4 of Phase II.
- Core samples will be collected from an acid gas disposal zone to examine the mineralogical and geomechanical changes that can occur in a carbonate rock exposed to high-pressure acid gas.
- Geomechanical data will be used to populate a database that will support the creation of a geomechanical model of the pinnacle reef.
- Geochemical modeling activities will be conducted to predict the long-term effects of acid gas injection on the reservoir and cap rock formations.
- A Regional Technology Implementation Plan will be developed.

Lignite for CO_2 Sequestration and Enhanced Coalbed Methane

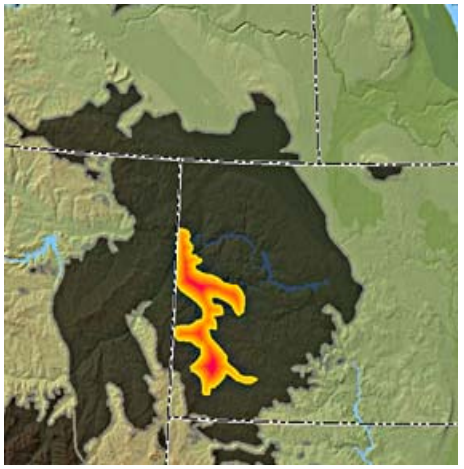
Lignite Goal and Objectives

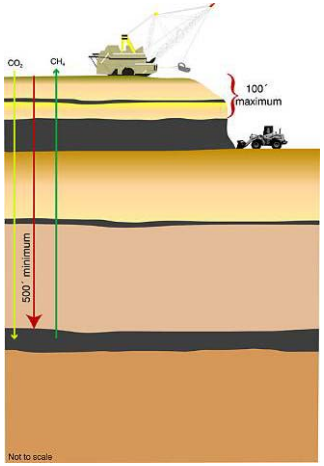
Goal

- Determine the feasibility of simultaneous CO_2 sequestration and natural gas production from a lignite coal seam.

Objectives

- Inject CO_2 into lignite coal seam and monitor CO_2 fate in the reservoir.
- Determine the potential for coalbed methane production from the lignite seam.
- Determine the potential for production enhancement by CO_2 injection.
- Develop Regional Technology Implementation Plan for CO_2 sequestration in lignite coal.





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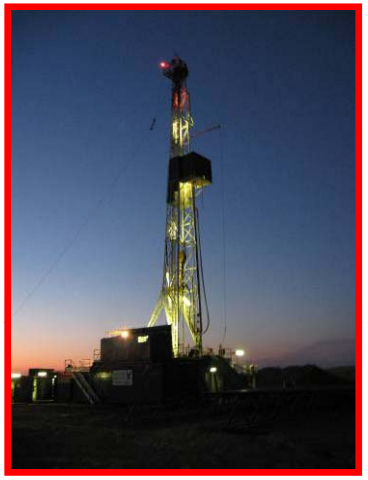
Key Results

- Well drilling is completed.
- Logging is completed, and logs are being processed in collaboration with Schlumberger.
- Core is collected, and its analysis by TerraTek is in progress.
- Initial numerical model has been created.
- Preliminary simulations have been run which provide guidance for the possible outcome of CO_2 injection activities in the coal seam.



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Path Forward

- Complete log processing and laboratory- and field-scale tests.
- Anticipated field-scale experiments.
  - Pump test
- Conduct well stimulation if appropriate.
- Use acquired log data, core analysis, and in situ monitoring data to create simulation model and begin modeling CO_2 fate.
- Begin CO_2 injection.
- Implement MMV program.
- Develop Regional Technology Implementation Plan.
- We are under tight-hole status until the test results can be evaluated.

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Prairie Pothole Wetlands/ Grasslands Field Validation Test

Prairie Pothole Wetlands / Grasslands Goal and Objectives

Goal: Validate and quantify carbon sequestration potential in the PPR wetlands and grasslands.

- Develop the technical capacity to systematically identify, develop, and apply alternate land use management practices to the prairie pothole ecosystem that will result in GHG reductions.
- Quantify the amount of carbon sequestered in restored wetland and surrounding grassland systems.
- Define best management practices for sequestering carbon and reducing GHGs in wetlands and grasslands.

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Prairie Pothole Wetlands/ Grasslands Path Forward

- Data processing/compilation.
- Determine business processes for carbon credit trading (aggregators).
- Develop Regional Technology Implementation Plan:
  - Field operations throughout the PCOR Partnership region.
  - Evaluation of other state and regional GHG or cap-and-trade programs – rules and policies.
  - Evaluation of DOE guidelines for aggregators and terrestrial offset providers.
  - Evaluation of voluntary carbon market, active players, certification standards, market activity, etc.

Safety, Regulatory, and Permitting Goal and Objectives

Goal: Assess the developing regulatory framework of the PCOR Partnership region.

- Analyze existing regulations and identify relevant authorities.
- Keep abreast of congressional actions and state/provincial regulatory activities.
- Provide guidance for field test activities.

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Safety, Regulatory, and Permitting Results

- Congressional actions and regional initiatives are tracked and analyzed for potential impact on the PCOR Partnership region as well as CO_2 sequestration as a whole.

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Regional Initiatives

- Regional Greenhouse Gas Initiative
- Western Climate Initiative
- The Climate Registry
- Midwestern Regional Greenhouse Gas Reduction Accord
- Individual state actions

Safety, Regulatory, and Permitting Results

- Interstate Oil & Gas Compact Commission
  - Carbon Capture and Geological Storage Regulatory Task Force
    - Draft model regulation and statute dealing with site licensing, well operation, well/site closure, and long-term storage were released last fall.

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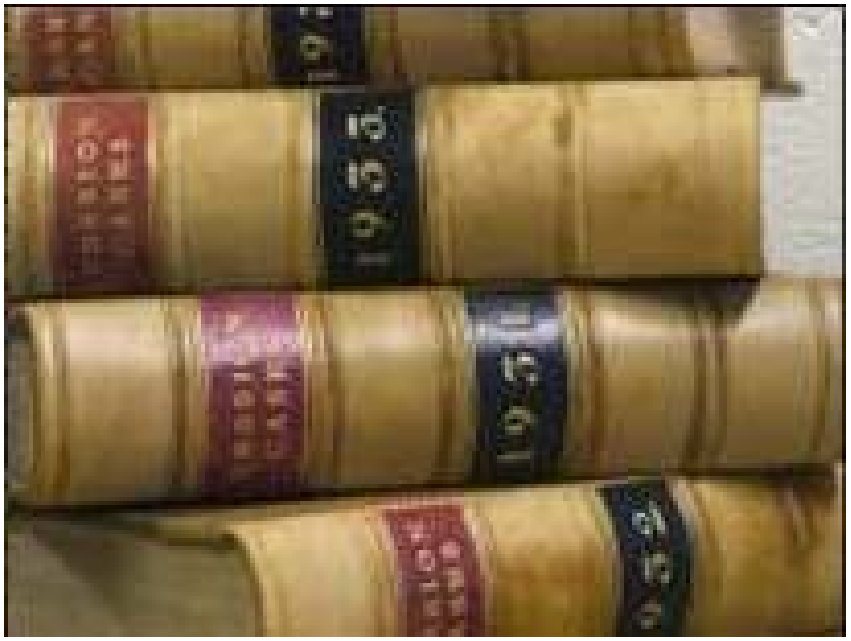
Safety, Regulatory, and Permitting Path Forward

- Continue to stay abreast of congressional actions and state/provincial regulatory activities.
- Provide guidance for field validation tests.
- Develop a roadmap document for various sequestration opportunities in the region, based on current field test requirements.



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Public Outreach and Education Goal and Objectives

Goal: Raise awareness of key stakeholders and the general public regarding sequestration opportunities in the region.

- Develop and deliver general outreach to benefit partners and to support field validation test activities.
- Support outreach of RCSPs.

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Public Outreach and Education Results

Consistent, fundamental information on CO_2 sequestration in a variety of readily usable formats

- Five videos (two completed, three in production)
- Over a dozen fact sheets
- Public Web site with monthly updates
- 50-page regional atlas.
- Over 20 technical reports

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Identification of Sequestration Technologies Goal and Objectives

The goal is to identify sequestration technologies and approaches suitable and available for large-scale deployment in the PCOR Partnership region.

- Economic assessment of representative source–technology–sink combinations.
- Development of Carbon Management Plans.
- Novel Sequestration Case Study (wind energy and CO_2 compression).

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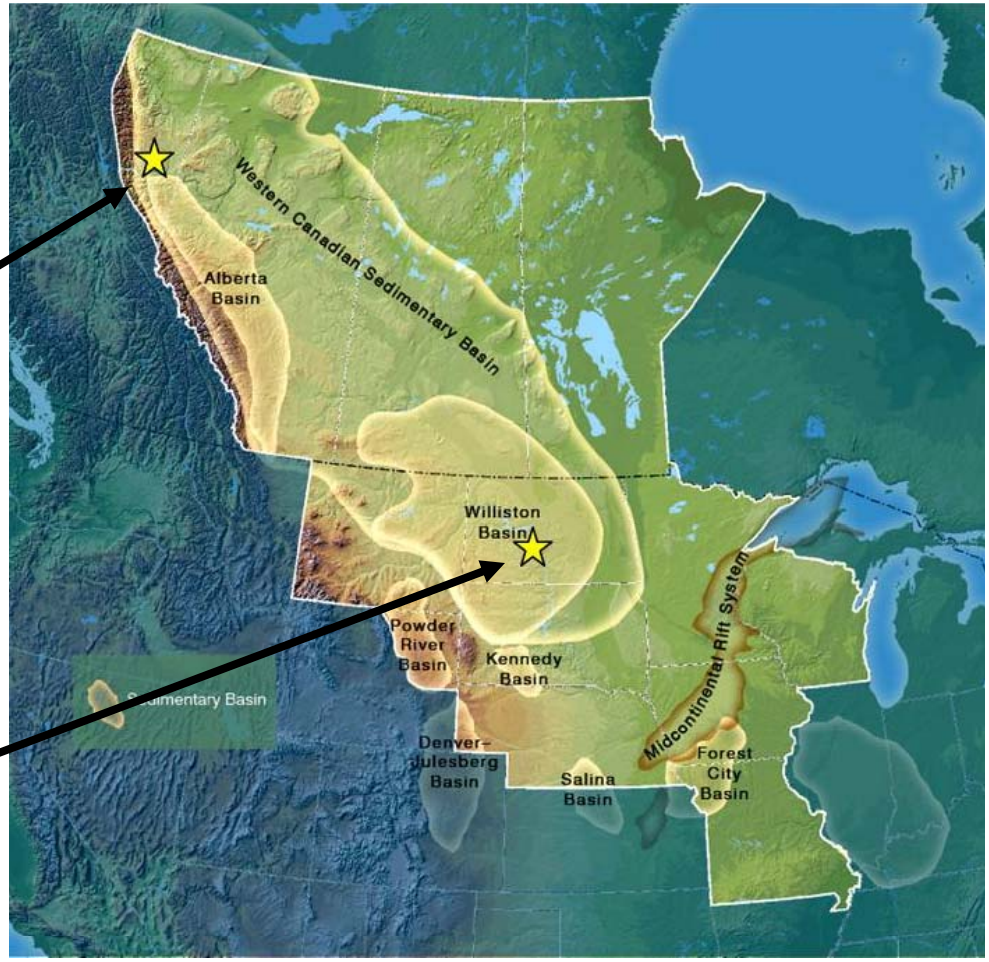
We Are Planning Two Phase III Efforts

Saline Formation Injection in Canada

Williston Basin Project



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PCOR Partnership Phase III Goals

- Meet or exceed our partners' expectations – develop a project that leads to commercial success.
- Develop infrastructure and expertise that propagate our region's competitive advantage into the future.
- Develop public support through outreach and education.
- Develop industry standards for MMV.
- Develop user-friendly standards for:
  - Site selection/permitting.
  - Risk assessment.
  - MMV.
- Develop markets and standards for the monetization of carbon credits.

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Why the Williston Basin?

- We have great Partners!
- The Williston Basin is perfect (both geologically and socioeconomically) for this demonstration.
- One of the first commercial-scale projects to capture CO_2 from a retrofitted coal-fired power plant (CFPP).

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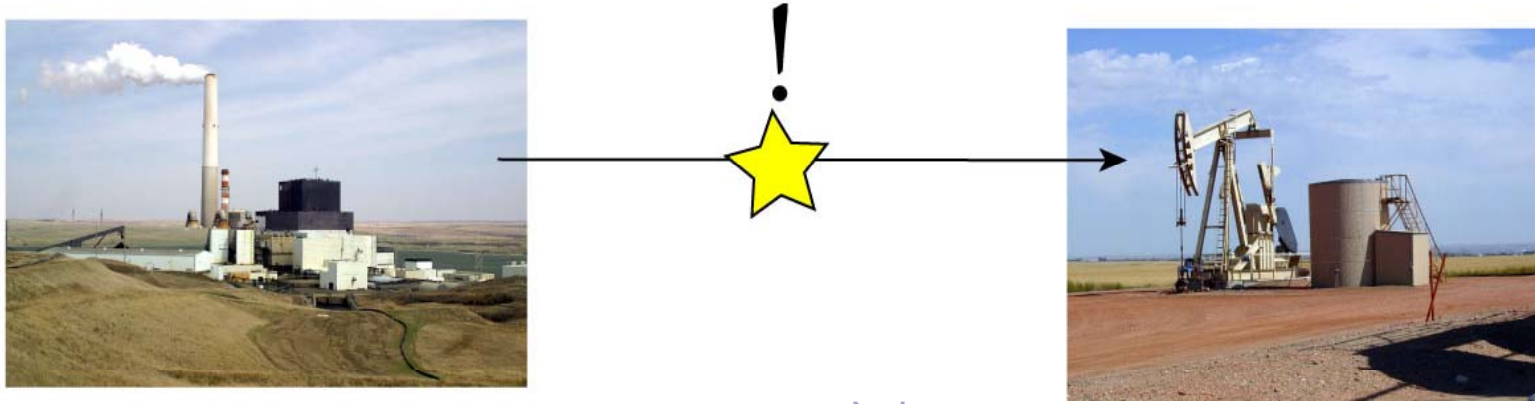
Williston Basin
Phase III – Concept

- Capture at least 500,000 t/yr of CO_2 at existing CFPP in central North Dakota.
- Transport via pipeline to Williston Basin oil field.
- Meet or exceed all of the DOE Phase III objectives.
- Conduct activities to document the efficacy of carbon capture and sequestration (CCS).
- Ultimately monetize credits.



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Williston Basin Phase III – Project Benefits

- One of the first commercial-scale projects to capture CO_2 from a retrofitted CFPP.
- One of the first large-scale implementations of cost-effective MMV plan based on proven industrial technology applications and regulatory processes.
- Utilization of existing technologies, methodologies, and frameworks to adapt existing regulatory processes for large-scale CCS.
- Economic benefits to North Dakota are very significant as lignite, oil, and gas are critical to our state's economy and provide vital primary sector and tax revenue.

PCOR Partnership

NETL

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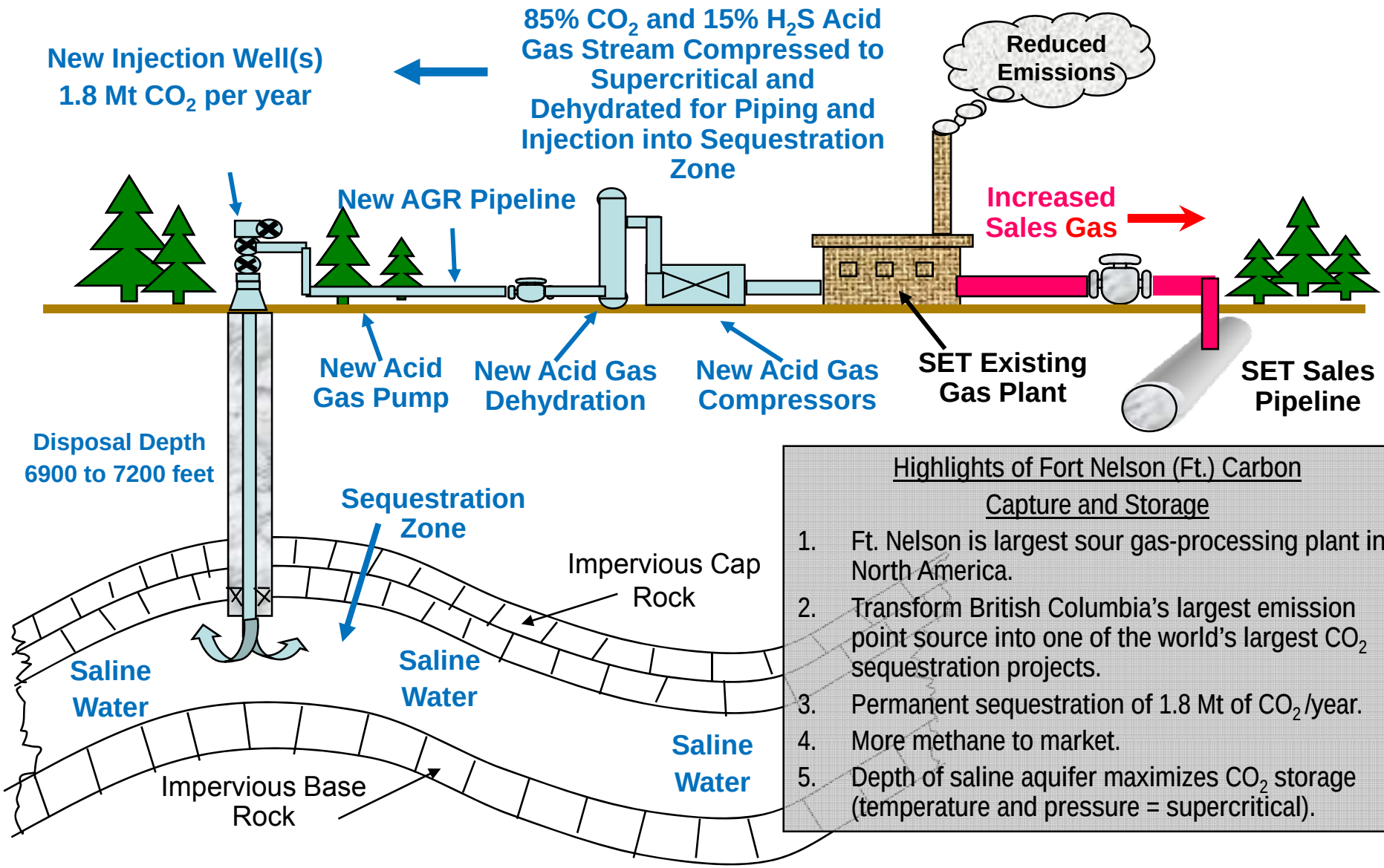
Fort Nelson CO_2 Sequestration Project



Highlights of Fort Nelson (Ft.) Carbon Capture and Storage

1. Ft. Nelson is largest sour gas-processing plant in North America.
2. Transform British Columbia's largest emission point source into one of the world's largest CO_2 sequestration projects.
3. Permanent sequestration of 1.8 Mt of CO_2/year.
4. More methane to market.
5. Depth of saline aquifer maximizes CO_2 storage (temperature and pressure = supercritical).

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